

## Lab 1: The Scientific Method

Name \_\_\_\_\_

Date \_\_\_\_\_

### Learning Objectives:

1. State the steps of the scientific method.
2. Define hypothesis and understand the criteria for making an appropriate hypotheses.
3. Define variable and differentiate between the independent variable, dependent variable, and control variables (standardized).
4. Understand ways to strengthen the evidence for a hypothesis.
5. For an experiment, be able to describe an appropriate hypothesis and conclusion, as well as list the different variables.
6. Understand data displayed using a bar graph. Create a graph to show your data and label appropriately.
7. Use an electronic balance correctly.

### Introduction:

Scientists use the scientific method to answer questions and provide explanations about natural phenomena. It is a logical process based on careful observation and experimentation (Figure 1). Depending on the experiment the process may vary, but typically there are five basic steps of the process which we will follow here.

The scientific method begins with an **observation** that leads to a question about the observed phenomena. Based on observations scientists generate a **hypothesis**, or tentative explanation for the observed phenomena. Hypotheses are written as statements and they must always be *testable* and *falsifiable*. A good hypothesis offers only one explanation and leads to predictions (often written as an “if-then” statement). The predictions are tested using carefully designed **experiments**. If possible, experiments should only test *one* factor at a time, with all other conditions being kept constant. Data collected from the experiments are **analyzed** and evaluated in respect to the original hypothesis statement, and **conclusions** are drawn. If the experiment has been designed properly, the data should either *support* or *reject* the hypothesis. If you can neither support nor reject the hypothesis statement, then the experiment has been poorly designed.

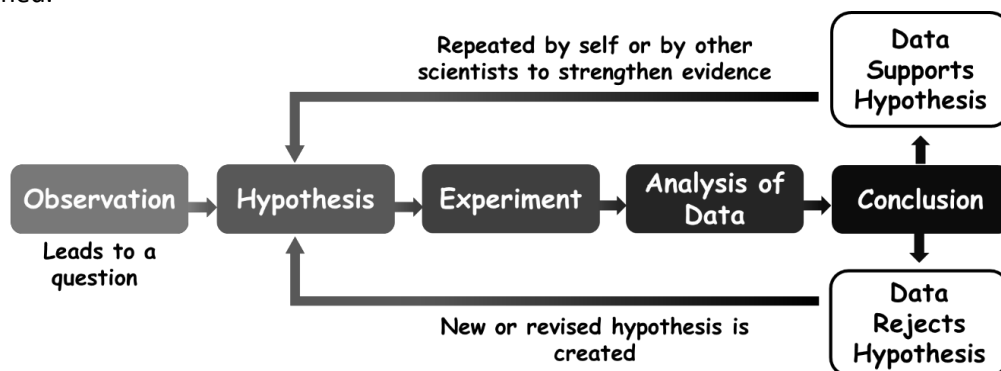


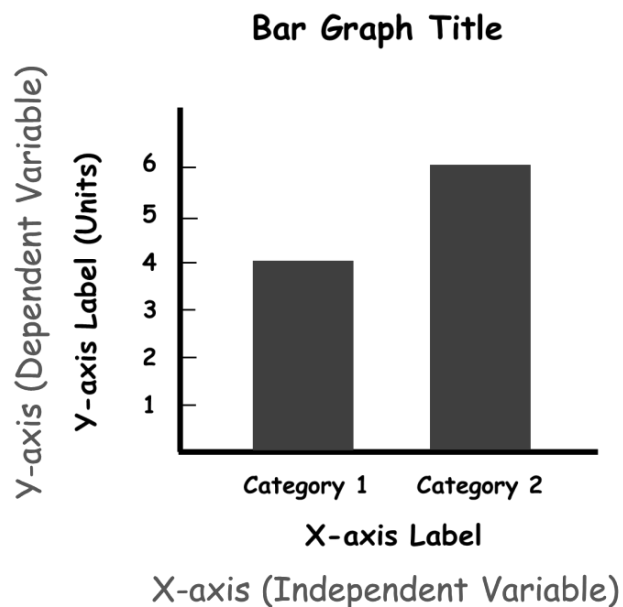
Figure 1. Steps of the scientific method.

The scientific method does not end here. If the experimental analysis leads to a rejection of the hypothesis, then a new or revised hypothesis statement is constructed and the process starts over. If the hypothesis is supported, further experimentation is still warranted. **Repetition** strengthens the evidence for hypotheses. It is important to remember that scientific inquiry is an ongoing process and *hypotheses are never considered to be proven*. New data may alter or even reject previously supported scientific explanations.

There are many different ways to apply the scientific method. Some involve direct experimentation in a lab under very controlled (standardized) conditions. Others, especially studies involving humans, involve collecting data with much more variability in the conditions. Depending on how much of this variability can be controlled for, the conclusions drawn may be quite tentative and limited.

In science, a variable is any item, factor, or condition that can be controlled or changed. Scientific experiments typically have three types of variables. The **independent variable** is the variable that is manipulated or changed by the scientist. The **dependent variable** is the variable that is observed or measured in the experiment. **Control variables** (also called constants) are not changed throughout the experiment. This allows the relationship between the dependent and independent variable being tested to be better understood.

Graphs and tables are visual tools often used to help scientist analyze the data collected from the experiment. The goal is to show a relationship between the variables of an experiment. **Bar graphs** are an effective way to compare sets of data between different groups or categorical data. When creating a bar graph, it is important to include an appropriate title, axis labels, and units. The vertical axis (Y-axis) typically represents the dependent variable of the experiment, while the horizontal axis (X-axis) represents the independent variable (Figure 2).



**Figure 2. Representation of the various parts of a bar graph.**

**Activity: How Much Does a Penny Weigh?**

In this lab, each lab station has a cup of pennies. You will be working as a team using the steps of the scientific method to determine a unique aspect of this piece of U.S. currency. Your instructor will assign your group a specific number. You are part of Group \_\_\_\_\_.

Materials Needed

For a team of four students, you need:

- Cup of 50 pennies
- Electronic scale
- Weigh boat

Exercise

You will use the *electronic balance* (used to determine mass) to complete the following. Make sure you keep track of all your data. **When using the scale, be sure to always first zero it out.** Designate one member of your group to write the results on the board.

1. Select one penny and determine its mass (use appropriate unit).
  - Mass of selected penny:
2. Determine the total mass of all the pennies at your lab station.
  - Total mass of all 50 pennies:
3. Calculate the average mass of each penny (average mass = total mass/number of objects).
  - Average mass of one penny:
4. Record the class results in table 1.

**Table 1. Class results on the mass of a penny (record your data under proper group and then collect other team's results)**

	Mass of a penny	Total mass of all 50 pennies	Average mass of a penny
Group 1			
Group 2			
Group 3			
Group 4			
Group 5			
Group 6			

5. Take a few minutes to discuss the results with your lab group and answer the following questions.
  - a. For the mass of a penny, are there any differences in the results between groups? Any similarities?
  - b. For the average mass of a penny, are there any differences in the results of between groups? Any similarities?

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6. Record three ideas to explain your observations (e.g., Pennies that are \_\_\_\_\_ have a higher mass than pennies that are \_\_\_\_\_.)

a.

b.

c.

The statements you have written are hypotheses. An observation leads to a question, a question leads to a hypothesis, the hypothesis is tested, data are analyzed, and conclusions are drawn.

7. Design an experiment to test one of your hypotheses. Use the following prompts to help write out the step by step process of your experiment (experimental design).

- Hypothesis being tested:
- Experimental design: (For each group of pennies being tested, you should use at least 10 pennies.)
- Experimental groups (further describes as Set A and Set B):

8. Determine the variables of your experiment.

- Independent variable (what are you changing?):
- Dependent variable (what are you measuring?):
- Controlled variables (what is constant between the two experimental groups):

9. Weigh each penny for Set A and record the data from your experiments in Table 2 below.

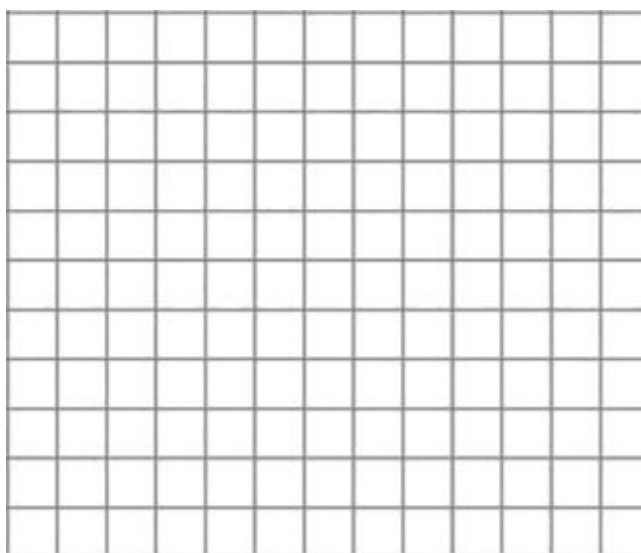
10. Calculate the average for Set A - add the mass of each penny in Set A and divide the total by 10 (the total # of pennies):

11. Repeat this process for each penny in Set B. Record your average for Set B:

**Table 2. Results of the penny experiment.**

	Mass (g)	
	Set A	Set B
Penny 1		
Penny 2		
Penny 3		
Penny 4		
Penny 5		
Penny 6		
Penny 7		
Penny 8		
Penny 9		
Penny 10		
Average*		

12. Present the data as a bar graph below. Make sure to include a title, axis labels, and units for your bar graph (refer to pg. 2). To create your bar graph, use the average mass of a penny for each group.



### Questions

1. Restate your hypothesis.
2. Did your results support or reject your hypothesis?
3. What is the conclusion you can draw from your experiment?
4. What should be the next step? (Think back to the Introduction: What do you do if you accept or reject a hypothesis)

**Post-Lab Activity:**

Name: \_\_\_\_\_

Read the example of an experiment conducted by a college student and answer the following questions.

Joseph started a car washing business at his home to earn some extra cash while going to college. His neighbor soon began complaining that her flowers were dying from the soap he uses to wash the cars. She is now threatening to go to the Homeowner's Association. Joseph does not believe that the soap is causing her flowers to die because he is using an environmental-friendly organic soap for his business. Additionally, his flowers are looking better than ever. He decided to take a scientific approach to prove to his neighbor that she is wrong. He developed the hypothesis that the organic soap he is using in his car wash business increases the growth of flowers. He made the prediction that if a flower is exposed to the car soap then it will grow faster than a flower not exposed to the soap. He decided to test the effects on sunflowers. He planted 10 flowers, each in its own pot with the same type of potting soil. All the flowers got the same amount of sun and the same amount of water; however, he added a drop of the organic soap to the water every time he watered five of the sunflowers. After four weeks, he measured the length of each flower. He found that the average growth of the sunflowers that were exposed to soap was 32 cm while the average growth of the sunflowers not exposed to soap was 31 cm. He created a bar graph to show his results (Figure 3). After analysis, he found there was no significant difference between the two groups. He presented the results to his neighbor and told her that while the soap might not cause the flowers to grow taller, he proved that the soap he used to wash cars does not kill flowers.



**Figure 3. Joseph's bar graph of his experiment of testing the organic soap on flower growth.**

1. What steps of the scientific method did Joseph use?
  
2. What was Joseph's hypothesis?
  - a. What are the criteria for an appropriate hypothesis?
  
  - b. Does Joseph's hypothesis fit the criteria of an appropriate hypothesis? Why or Why not?

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3. What is the dependent variable of Joseph's experiment?
4. What is the independent variable of Joseph's experiment?
5. What are some of the control variables (constants) of Joseph's experiment?
6. Joseph's conclusion was: While the soap might not cause the flowers to grow taller, he proved that the soap he used to wash cars does not kill flowers. Was his conclusion correct? Why or Why not? *(Think back to his original hypothesis and what was being tested.)*
7. Name at least one factor or variable that Joseph may not have accounted for.
8. What is missing from the bar graph Joseph created?